

APPLICATION
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*Title: Method, System and Computer Program Product for Monitoring and Optimizing
Fluid Extraction from Geologic Strata*

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FIELD OF INVENTION

5 The present invention relates generally to a data processing method, system and computer program product and more specifically to a low cost method, system and computer program product for monitoring and optimizing fluid extraction from geologic strata. The invention further provides energy savings and limits pumping equipment wear and tear by minimizing pump runoff conditions.

BACKGROUND

10 Maximizing the recovery of petroleum from marginally productive domestic oil fields is important to U.S. energy independence goals and national security interests. However, in order to be competitive with imported petroleum, the domestic petroleum must be recovered in a cost efficient manner in order to be commercially viable. Traditionally, techniques for the pumping of petroleum involved either continuously operating a pump unit or controlling the pumping unit with a simple electromechanical timer to avoid peak electrical energy charges. Neither of these techniques is suitable for optimizing the extraction of petroleum from marginally productive oil fields.

15 Furthermore, these techniques waste electrical energy and cause excessive wear and tear on the pumping equipment, thus increasing operational and maintenance costs which decreases the economic viability of the operation. As a result, marginally productive oil fields are often underutilized due to the high electrical energy costs incurred and resulting low production yields resulting from the production wells.

25 In order to efficiently extract petroleum from these marginal oil fields, a system should be employed which detects when a pumping system encounters an abnormal pumping situation. For example, a commonly encountered abnormal pumping situation is known as "fluid pound".

Fluid pound occurs when the drawing well is pumped-off, i.e., when petroleum is extracted from a well at a rate greater than the rate at which the petroleum is recharged by the petroleum bearing formation. In a pump-off situation, a working well is only partially filled during an upstroke of a plunger. Upon the plunger's downstroke, the plunger strikes or "pounds" the remaining fluid in the working well causing severe jarring of the entire pumping unit which may lead to damage of the pumping unit and decreased pumping efficiency.

Many solutions are known in the relevant art to address the pump-off situations in a petroleum production environment. For example, several references teach measuring changes in the load on a reciprocating member associated with a downhole pump; US 3,838,597 to Montgomery, et al.; US 4,286,925 to Standish; US 5,044,888 to Hester; US 6,155,347 to Mills; measuring current and voltage phase relationships associated with an electrical driving motor US 5,362,206 to Westerman, et al.; measuring the instantaneous rate of both pulsating and steady-state flow; US 5,006,044 to Walker et al.; measuring vibrations incident on reciprocating member associated with a downhole pump, SPE 62865, "Marginal Expense Oil Well Wireless Monitoring," D.Nelson, H.Trust, Society of Petroleum Engineers, 2000; sonically measuring pump-off, US 4,171,185 to Duke, et al.; and expensive hybrid computer controlled systems monitoring a plurality of pump operating parameters, US 5,941,305 to Thrasher, et al.

Although many of these solutions may be effective, these solutions tend to have one or more disadvantages including requiring expensive monitoring equipment, requiring frequent calibration and/or requiring frequent maintenance in the corrosive and toxic environment of marginally productive petroleum fields. As such, the added incremental costs of providing one or more of these solutions generally limit their application to larger and more productive fields. Smaller and marginally productive fields necessarily require low cost and low maintenance solutions in order to be economically viable.

Therefore, it would be highly advantageous to provide a simple, low cost monitoring and control system which maximizes recovery of petroleum, minimizes energy usage and requires minimal ongoing maintenance.

SUMMARY

5 This invention addresses the limitations described above and provides in a first embodiment, a method for monitoring and optimizing fluid extraction from geological strata which comprises coupling a flow transducer to a flap valve (either pre-existing or newly installed) to a discharge conduit associated with a positive displacement pump. The flow transducer is designed to generate flow
10 signals by detecting movement of a position detectable flap element internal to the flap valve by way of one or more different sensing mechanisms including variable reluctance effects, Hall effects, magnetic inductance effects, binary switch states, potentiometer outputs or piezoelectric effects. The position detectable flap element includes means (mechanical, electrical or magnetic) for stimulating the
15 flow transducer to generate the flow signals coincident with movement of the flap element.

 The method embodiment of the invention further provides for electromagnetically coupling the flow transducer to a local supervisory control system, monitoring the flow signals at least during operation of the positive
20 displacement pump, accumulating at least a portion of the flow signals in a memory associated with the local supervisory control system, and determining an optimum pumping cycle from the accumulated flow signals.

 In a related method embodiment, an arrangement is provided for transferring at least a portion of the accumulated flow signals from the local
25 supervisory control system to a centralized supervisory control system, outputting the optimized pumping cycle in a format useful for optimizing fluid extraction from the geological strata using the positive displacement pump.

5 The flow signal transfer process may be accomplished using a telecommunications link, a laptop computer, a personal data assistant, or a data logging device, the flow data transferred from which are then retrievably stored in a data store associated the centralized supervisory control system. The telecommunications link may include electrical, optical, radio frequency or a combination thereof.

10 In another related method embodiment, an arrangement is provided for electromagnetically coupling a motor controller associated with the positive displacement pump to the local supervisory control system, generating a control signal if the flow signals fall outside a predetermined range or predetermined set point, sending the control signal to the motor controller, and changing an operating state of the positive displacement pump by the motor controller upon receipt of the control signal. The aforementioned predetermined range and predetermined set point includes low or loss of fluid flow and a flow duration in
15 which the positive displacement pump has been operating or idle respectively. The operating state of the positive displacement pump may be turned on or off based on information derived from the flow signals.

20 In another method embodiment, the invention further provides for determining an optimum pumping cycle from the accumulated flow signals, and outputting the optimized pumping cycle in a format useful for optimizing fluid extraction from the geological strata.

25 In a systematic embodiment of the invention, a system for monitoring and optimizing fluid extraction from geological strata is provided which comprises: a flow transducer coupled to a flap valve (either pre-existing or newly installed). The flow transducer is designed to generate flow signals by detecting movement of a position detectable flap element internal to the flap valve by way of one or more different sensing mechanisms including variable reluctance effects, Hall effects, magnetic inductance effects, binary switch states, potentiometer outputs or piezoelectric effects.

The position detectable flap element includes means (mechanical, electrical or magnetic) for stimulating the flow transducer to generate the flow signals coincident with movement of the flap element. By way of example, the position detectable flap element includes one or more permanent magnets attached thereto and arranged to stimulate the flow transducer to generate the flow signals coincident with flow induced movement of the position detectable flap element.

The system further provides for a local supervisory control system which is electromagnetically coupled to the flow transducer. The local supervisory control system includes; a first processor; a first memory coupled to the first processor; and an application operatively stored in a portion of the first memory having logical instructions executable by the first processor to; monitor the flow signals generated by the flow transducer during operation of the positive displacement pump, accumulate the flow signals in another portion of the first memory and transfer the accumulated flow signals to an electronic transport medium. Transferring of the accumulated flow signals may occur automatically based at least in part on time, in response to a transfer request issued by the centralized supervisory control system or in response to an event (flow based, detected error condition or coupling of the electronic transport medium to the local supervisory control system.)

The electronic transport medium includes a telecommunications link, a laptop computer, a personal data assistant, or a data logging device. The telecommunications link may include electrical, optical, radio frequency or a combination thereof. In an embodiment of the invention, the telecommunications link is a wireless network.

In a related systematic embodiment, the invention further comprises: a centralized supervisory control system including; a second processor; a data store coupled to the second processor; a second memory coupled to the second processor; and another application operatively stored in a portion of the second memory having logical instructions executable by the second processor to; receive the accumulated flow signals from the electronic transport medium, retrievably store the accumulated flow signals in the data store and output the accumulated flow signals in a format useful for optimizing fluid extraction from the geological strata using the aforementioned positive displacement pump.

In another related systematic embodiment, the application associated with the local supervisory control system further includes instructions executable by the first processor for; transmitting a control signal to an electromagnetically coupled motor controller associated with the positive displacement pump if the flow signals fall outside a predetermined range or predetermined set point.

The aforementioned predetermined range and predetermined set point includes low or loss of fluid flow and a flow duration in which the positive displacement pump has been operating or idle respectively. The operating state of the positive displacement pump may be turned on or off based on information derived from the flow signals.

In a systematic embodiment of the invention, the motor controller includes a timer mechanism for turning the positive displacement pump on or off in accordance with a programmed pumping cycle which can be modified either manually or automatically to utilize the determined optimized pumping cycle.

In another systematic embodiment, the invention provides for generating a control signal if the flow signals fall outside the predetermined range, the flow signals fall outside the predetermined set point, or a control command is received from the centralized supervisory control system. The control command may be generated by the central supervisory control system periodically (time-based) or as a result of an event (flow based or detected error state.)

In a computer program product embodiment of the invention, the invention comprises a computer program product embodied in a tangible form readable by a processor having executable instructions stored thereon for causing the processor to: monitor flow signals generated by a flow transducer, accumulate
5 at least a portion of the flow signals in a memory coupled to the processor, transmit a control signal to an electromagnetically coupled motor controller if the flow signals fall outside a predetermined range or predetermined set point, transfer at least a portion of the accumulated flow signals over a network to another processor, and output the accumulated flow signals in a format useful for
10 optimizing fluid extraction from geological strata using a positive displacement pump.

The programs and associated data may be stored in semi-conductor storage media, transportable digital recording media such as a CD ROM, floppy disk, data tape, DVD, or removable hard disk for installation on the centralized supervisory
15 control system or local supervisory control system as one or more transportable computer program products. The programs and associated data comprise executable instructions which are stored in a code format including byte code, compiled, interpreted, compliable or interpretable.

BRIEF DESCRIPTION OF DRAWINGS

5 The features and advantages of the invention will become apparent from the following detailed description when considered in conjunction with the accompanying drawings. Where possible, the same reference numerals and characters are used to denote like features, elements, components or portions of the invention. It is intended that changes and modifications can be made to the described embodiment without departing from the true scope and spirit of the subject invention as defined in the claims.

10 FIG. 1 – is a generalized block diagram of a centralized supervisory control system.

FIG. 1A – is a generalized block diagram of a local supervisory control system.

15 FIG. 2 – is a detailed block diagram of one embodiment of the invention depicting the interrelationship of the local supervisory control system, fluid extraction pumping system and a flow transducer.

FIG. 3 – is a detailed block diagram of one embodiment of the invention depicting the interrelationship of the local supervisory control system, fluid extraction pumping system flow transducer and the centralized supervisory control system.

20 FIG. 4 – is a detailed block diagram of one embodiment of the invention depicting a motor controller and programmable time coupled to an electric motor which drives the fluid extraction pumping system.

25 FIG. 5 – is a flow diagram of an embodiment of the invention depicting a process arrangement and the major logic incorporated into the local supervisory control system and centralized supervisory control system.

FIG. 5A – is another flow diagram of an embodiment of the invention depicting a process arrangement and the major logic for providing control signals based on monitored flow signals.

Appendix 1 – Example C language source code for use in the local supervisory control system.

DETAILED DESCRIPTION

5 This present invention provides an arrangement which utilizes an inexpensive flow transducer and a simple local supervisory control system to monitor and/or control the operation of a positive displacement pump used to extract petroleum from geologic strata. The local supervisory control system controls the operation of an electric motor which drives a reciprocating positive displacement pump so as to maximize the volume of petroleum extracted from the well per pump stroke while minimizing electricity usage and pump-off situations. 10 By reducing the electrical demand and pump-off (i.e., “pounding” or “fluid pound”) occurrences, operating and maintenance costs should be reduced sufficiently to allow petroleum recovery from marginally productive petroleum fields. The local supervisory control system includes one or more applications to at least collect flow signal data generated during operation of the positive displacement pump. No flow, low flow and flow duration are easily evaluated using a flap valve/flow transducer arrangement. The applications are envisioned to be programmed in a high level language such as Java TM, C++, C, C#, or Visual Basic TM. 15 An example C based program is provided in Appendix 1 to this specification and is herein incorporated by reference. Alternately, applications written for a local supervisory control system may be programmed in assembly language specific to the processor deployed. 20

Referring to Figure 1, a functional block diagram of a centralized supervisory control system 105 is shown which includes a central processor 5, a main memory 10, a display 20 electrically coupled to a display interface 15, a secondary memory subsystem 25 electrically coupled to a hard disk drive 30, a removable storage drive 35 electrically coupled to a removable storage unit 40 and an auxiliary removable storage interface 45 electrically coupled to an auxiliary removable storage unit 50. 25

A standard desktop, workstation, or laptop may be used as the centralized supervisory control system; however, a computer system arranged in a server configuration may be advisable when large numbers of local supervisory control systems are intended to be centrally managed.

5 A communications interface 55 subsystem is coupled to a network 65 via a network interface 60. An output device 75 such as a printer or plotter is operatively coupled to the communications interface 55 via an output device interface 70. User input devices such as a mouse and a keyboard 85 are operatively coupled to the communications interface 55 via a user interface 80.
10 The auxiliary removable storage unit 50 may include a data logging device which allows the transfer of accumulated flow data to be collected in the field and downloaded into the centralized supervisory control system for analyses rather than receiving the accumulated flow data over the network 65.

The central processor 5, main memory 10, display interface 15 secondary
15 memory subsystem 25 and communications interface system 55 are electrically coupled to a communications infrastructure 100, commonly known as an I/O bus. The centralized supervisory control system 105 includes an operating system, at least one analytical application for at least receiving and reading flow signal data and generating an output of the flow signal data in a format useful for
20 determining an optimum pumping cycle. Additional capabilities of the application include periodically polling or interrogating a local supervisory control system to retrieve the flow signal data and issue control commands to the local supervisory control system. The analytical application may be a standard spreadsheet type office suite application or a proprietary application written
25 specifically for reading and analyzing the flow signal data.

The network 65 includes wireless networks such as BlueTooth, HomeRF, IEEE 802.11 a/b/g and its successors or cellular wireless networks. IEEE 802.20 wired or optical networks may also be employed to communicate with one or more local supervisory control systems addressable over the network 65.

Referring to FIG. 1A, a functional block diagram of the local supervisory control system is shown 110. The local supervisory control system 110 essentially incorporates the same modular components included in the centralized supervisory control system described above but may lack the hard disk drive 30 and display equipment 15n, 20n for power conservation.

The local supervisory control system includes a processor 5n, volatile memory 10a, an optional display 20n electrically coupled to an optional display interface 15n, a non-volatile memory 10b and an electrically erasable programmable read only memory (EEPROM) 10c. The volatile and non-volatile memory 10a, 10b are primarily intended for storage of flow data received from a flow transducer. In addition, the EEPROM 10c is intended to contain a run time operating environment and at least one data acquisition and storage application. Additional control applications may also be installed in the non-volatile memory 10b to generate control signals. One skilled in the art will appreciate that many memory management configurations are possible including the use of programmable read only memory (PROM).

A communications interface 55n subsystem is coupled to the network 65 via a network interface 60n, a data logging device 50 is coupled to coupled to a data logging interface 50n and a user interface arrangement 85n is coupled to a user device interface 80n and one or more local communications ports 95n are coupled to a communications port interface 90n. The processor 5n, volatile memory 10a, optional display interface 15n, non-volatile memory 10b, EEPROM (or PROM) 10c and communications interface system 55n are electrically coupled to a communications infrastructure 100n.

The local communications ports 95n includes standardized serial communications protocols such as RS-232, RS422, RS423, RS485, or USB. Alternately current loop (4- 20mA) arrangements with an analog to digital (A/D) converter will work as well.

The local communications ports 95n are intended to interface with a flow transducer and optionally a motor controller and/or programmable timer associated with an electric motor which drives a positive displacement pump.

5 The local supervisory control system 110 further includes an operating system either loaded into the EEPROM 10c or at least a portion of the non-volatile memory 10b along with at least one data acquisition and storage application and one or more communications applications. Optionally control applications may be installed to generate and send control signals to the motor controller and/or programmable timer.

10 Referring to FIG. 2, an example arrangement is depicted where extraction of petroleum from the well 225 is being accomplished using a walking beam type pumping unit 200. This type of pumping unit is typically driven by an electric motor 265. The electric motor 265 is coupled to a motor controller 260 or motor control center which controls the operation of the electric motor 265 and hence
15 that of the pump 200.

The electric motor 265 turns a drive belt assembly 255 which causes the walking beam portion of the pumping unit to rise and fall around a pivot point. On a pump upstroke, a traveling valve 210 is closed and the weight of the petroleum fluid in a capture volume 215 is supported by a cable 240 (sucker rod string),
20 allowing fluid to enter a pump barrel 220 through a standing valve 205. On a downstroke, the petroleum fluid in the pump barrel 220 forces traveling valve 210 to open, transferring the fluid load from the cable 240 to the discharge conduit 230.

25 The discharge of petroleum fluid flows 295 through the discharge conduit 230 and through a flap valve 290. The flap valve 290 is installed in line with the discharge conduit 230 of the downhole pump 230. A flow transducer 275 is coupled to the flap valve 290 which detects movements of an internal flap element 285 caused by the flow of petroleum 295 through the flap valve assembly 290.

The flap valve 290 is usually pre-existing in the discharge conduit 230 and is used as a check valve to prevent the backflow of the extracted fluid 295. As such, only a simple modification is required to be made to the existing flap valve 290. In one embodiment of the invention, the flap element 285 includes or is modified (pre-existing flap valves) to include at least one permanent magnet 287 or an equivalent flow signal generating arrangement. Examples of other acceptable methods of detecting movement of the flap element 285 include variable reluctance effects, Hall effects, magnetic inductance effects, binary switch states (using a reed switch), variable voltage or current (using a potentiometer) flows or piezoelectric effects. In the magnetic embodiment of the invention, movement of the flap element 285 induces a current flow, voltage flow or magnetic field in a sensing element portion 280 of the transducer 275.

The actual detection mechanism employed will likely depend on cost considerations, accessibility of existing check valves, and ability to perform maintenance on the flap valve 290, flap element 285 and flow transducer 275 and sensing element 280. In existing installations, the valve core including the flap element 285 is removed from the valve body 290 and one or more permanent magnets 287 are affixed to the flap element 285. The magnet(s) may be affixed using common fasteners and/or a permanent adhesive (e.g., self-threading bolts, rivets, nut and bolt arrangements or an epoxy adhesive). Alternately, a simple metal bracket having the permanent magnet(s) affixed with a permanent adhesive may then be attached to the flap element 285 using one or more of the fasteners.

In new installations, the construction of the flap element 285 may be of a low cost material compatible with the petroleum fluid and associated vapors such as polyvinyl chloride (PVC), other compatible synthetic polymeric materials or corrosion resistant metal alloys. An example of a flap valve having a suitable flow transducer for use in this invention is described in US 5,236,011 to Casada, et al.

Movement of the flap element 285 causes a flow signal to be transmitted over a communications link 95n to the local supervisory control system 110. The communications link may employ electrical, optical or wireless technologies; however, cost considerations may favor a wireless arrangement such as BlueTooth.

Depending on the type of flow transducer 275 employed, an A/D converter and a line transmitter may be required to communicate with the local supervisory control system 110. A delay circuit or logic may also be included to allow sufficient fluid flow to be generated during pump startup. The flow signals generated by the transducer 275 are accumulated in the memory of the local supervisory control system 110. In one embodiment of the invention, the accumulated flow signals are transferred to a centralized supervisory control system over a telecommunications network 65.

Transferring of the accumulated flow signals may occur automatically based at least in part on time, in response to a transfer request issued by the centralized supervisory control system 105 or in response to an event including flow based events, detected error conditions or coupling of the data logging device to the local supervisory control system 110. The data logging device may include a dedicated data logger, a laptop computer, a personal data assistant (PDA), or a PDA equipped cellular telephone adapted to communicate with the centralized supervisory control system 110.

In another embodiment of the invention, the local supervisory control system 110 is coupled to the motor controller 260 by way of another communications link 95n'. In this embodiment of the invention, the local supervisory control system 110 both monitors and accumulates the flow signals sent from the flow transducer 275 and includes logic to send control signals to the motor controller 260 as is shown in Table 1 below. One skilled in the art will appreciate that other logic arrangements may be employed as well.

Table 1

A task/state model algorithm is employed; tasks are intended to be executed simultaneously through time slicing, cooperative multitasking or interrupts; each task is assumed to be in one state at any given time. Variables are shown as [description]. Conditional expressions are shown as (thus).

TASK 1: SENSOR POLLING

State 0 - Initialize if (valve closed)

Transition to valve closed state

State 1 - Valve closed

if (valve open signal detected)

save [time at which opening detected] transition to valve
open state

State 2 - Valve open

if (valve closed signal detected)

save [time at which closing detected] compute duration of
time valve was open add time to [total duration of
open time]

else if (maximum valve open time exceeded) set stuck valve
error flag

Table 1 Continued

TASK 2: COMPUTATION OF FLOW AMOUNT

State 0 - Initialize

set [total duration of open time] to zero (always) transition
to waiting/pump on state

5

State 1 - Waiting/Pump On

if (inactive period elapsed)

if ([total duration of open time] < limit) set [total duration
of open time] to zero turn pump off record time of
pump turning off transition to pump off state

10

if (maximum pump on time elapsed) set [total duration of
open time] to zero turn pump off record time of
pump turning off transition to pump off state

State 2 Pump Off

if (preset pump off time exceeded) turn pump on record
time of pump turning on transition to waiting/pump
on state

15

TASK 3: COMMUNICATION

State 0 - Initialize

set [percent of time open] array elements to zero (always)
transition to wait for transmit time state

20

State 1 - Wait for Recording Time

if (error condition detected) transmit error code
immediately

25

if (wait time elapsed) compute new value of percent time
valve open transition to recording/transmitting state.

Table 1 Continued

State 2 - Recording/Transmitting

save [percent of time open] in array

if (time between data transmissions elapsed) transmit ID

and header information transmit data from array of

percent times open transmit data from array of

pump on/off data transmit end of data signal and

checksum(s)

(always) transition to wait for recording time state.

Referring to FIG. 3, another embodiment of the invention is depicted where the local supervisory control system 110 is in processing communications over a telecommunications network 65 with a centralized supervisory control system 105. In this embodiment of the invention, the centralized supervisory control system 105 periodically polls and/or interrogates the local supervisory control system 110 for accumulated flow signal data obtained from the flow transducer 275. The centralized supervisory control system 105 may also include the ability to determine an optimum pumping cycle in which the motor controller 260 should be operated to maximize petroleum withdrawal from the well 225 shown in FIG. 1, minimize electrical power usage of the electric motor 265, minimize wear and tear on the well pump and drive system 255 and reduce well pump-off. At least one analytical application is provided for receiving and reading flow signal data and generating an output in a format useful for determining an optimum pumping cycle. The analytical application may be a standard spreadsheet type office suite application or a proprietary application written specifically for reading and analyzing the flow signal data. Alternately, the optimum pumping cycle may be determined by an operator after reviewing the accumulated flow signal data.

In one embodiment of the invention, the local supervisory control system 110 includes a telecommunications link 95n' with the motor controller 260 and/or a programmable timer 310 coupled to the motor controller 260. In this embodiment of the invention, an optimized pumping cycle is generated by the centralized supervisory control system 105, sent over the network 65 to the local supervisory control system 110 and downloaded over the telecommunications link 95n' to the motor controller 260 and/or a programmable timer 310.

An equivalent automated programming of other motor controllers and/or programmable timers is envisioned using other local supervisory control systems in processing communications over the network 65 with the centralized supervisory control system 105. In another embodiment of the invention, the centralized supervisory control system 105 determines an optimized pumping cycle and provides an output on an output device 75 such as a printer or plotter. The output is then used by an operator to manually program the motor controller 260 and/or a programmable timer 310. In an embodiment of the invention, control commands can be sent from the centralized supervisory control system 105 to the local supervisory control system 110 to upload or transfer the accumulated flow signals or to turn the associated positive displacement pump on or off. The control commands may be issued periodically (time based) or in response to a flow based event or detected error state.

Lastly, the centralized supervisory control system 105 is further provided with a data store 30 for maintaining and archiving of flow signal data received from one or more local supervisory controllers over the network or by way of data logging device downloading. The data store 30 is envisioned as a database or parseable file.

Referring to FIG. 4, a more detailed view of the motor controller 260 and programmable timer 310 is provided. In one embodiment of the invention, the motor controller and/or programmable timer are coupled to the local supervisory control system via the telecommunications link 95n'. In another embodiment of the invention, the motor controller and/or programmable timer are manually programmed by the operator based on the output obtained from the centralized supervisory control system.

Referring to FIG. 5, a flow chart is provided which illustrates the major process arrangements implemented by the various embodiments of the invention. The process is initiated 500 by the installation or modification of an existing flap valve inline with the discharge conduit associated with a positive displacement pump installed on a petroleum recovery well. A flow transducer which is adapted to sense movement of a flap element internal to the flap valve is then coupled to the flap valve 504. The flow transducer is then electromagnetically coupled to a local supervisory control system 506 which monitors the flow signals generated by the flow transducer at least during operation of the positive displacement pump 508.

The local supervisory control system determines if one or more of the flow signals are out of range or exceed a set point 510. If one or more monitored flow signals are out of range or exceed a set point 510, a control sequence 511 is initiated as described in the discussion for FIG. 5A. If no flow signals are out of range or exceed a set point 510, at least a portion of the monitored flow signals are accumulated in a memory of the local supervisory control system 514. When requested or periodically, at least a portion of the accumulated flow signals are transferred to the centralized the centralized supervisory control system 516 where at least a portion of the transferred flow signals are stored in a data store 518 such as a database or parseable file.

The centralized supervisory control system then determines an optimum pumping cycle from the accumulated flow signals 520 and provides an output in a useful form for operating the positive displacement pump 522. The output is then used to update a timer associated with positive displacement pump 524. The process ends until another optimized pumping cycle is determined 528.

Referring to FIG. 5A, if one or more monitored flow signals are out of range or exceed a set point, a control sequence is initiated 511. The control sequence may be initiated due to a low or lost flow condition, flow duration exceeded, flow idle too long, flow transducer failure, system reset, transfer command received, or an error state detected 512. A control signal is then generated 513 and sent to at least a motor controller 515. The motor controller then causes a change in the operating state of the positive displacement pump. The process continues to accumulate at least a portion of the monitored flow signals in memory 519 as is provided in the discussion for FIG. 5. In another embodiment of the invention, one or more event signals are also sent to the centralized supervisory control system for logging, operator interaction and archival purposes 521.

The foregoing described embodiments of the invention are provided as illustrations and descriptions. They are not intended to limit the invention to precise form described. In particular, it is contemplated that functional implementation of the invention described herein may be implemented equivalently in hardware, software, firmware, and/or other available functional components or building blocks. No specific limitation is intended to a particular operating environment. Other variations and embodiments are possible in light of above teachings, and it is not intended that this Detailed Description limit the scope of invention, but rather by the Claims following herein.